

## Refereed papers

# The feasibility of using UML to compare the impact of different brands of computer system on the clinical consultation

Pushpa Kumarapeli BSc (Hons)

Research Assistant, Primary Care Informatics, Division of Community Health Sciences, St George's University of London, UK and PhD Student Faculty of Computing, Information Systems and Mathematics, Kingston University, Kingston upon Thames, UK

Simon de Lusignan BSc MSc MD FBCS CITP FRCGP

Reader, Primary Care Informatics, Division of Community Health Sciences, St George's University of London, UK

Phil Koczan MBBS FRCGP DMI (RCS Ed)

General Practitioner, Churchill Medical Centre, London, UK

Beryl Jones PhD

Senior Lecturer, Faculty of Computing, information Systems and Mathematics, Kingston University, Kingston upon Thames, UK

Ian Sheeler MSc BSc (Hons)

Courseware Developer, Primary Care Informatics, Division of Community Health Sciences, St George's University of London, UK

## ABSTRACT

**Background** UK general practice is universally computerised, with computers used in the consulting room at the point of care. Practices use a range of different brands of computer system, which have developed organically to meet the needs of general practitioners and health service managers. Unified Modelling Language (UML) is a standard modelling and specification notation widely used in software engineering.

**Objective** To examine the feasibility of UML notation to compare the impact of different brands of general practice computer system on the clinical consultation.

**Method** Multi-channel video recordings of simulated consultation sessions were recorded on three different clinical computer systems in common use (EMIS, iSOFT Synergy and IPS Vision). User action recorder software recorded time logs of keyboard and mouse use, and pattern recognition software captured non-verbal communication. The outputs of these were used to create UML class and sequence diagrams for each consultation. We compared

'definition of the presenting problem' and 'prescribing', as these tasks were present in all the consultations analysed.

**Results** Class diagrams identified the entities involved in the clinical consultation. Sequence diagrams identified common elements of the consultation (such as prescribing) and enabled comparisons to be made between the different brands of computer system. The clinician and computer system interaction varied greatly between the different brands.

**Conclusions** UML sequence diagrams are useful in identifying common tasks in the clinical consultation, and for contrasting the impact of the different brands of computer system on the clinical consultation. Further research is needed to see if patterns demonstrated in this pilot study are consistently displayed.

**Keywords:** attitude to computer, decision modelling, family practice, general practice, observation, process assessment, professional–patient relations, video recordings

## Introduction

UK general practice is universally computerised, and over time the computer has become increasingly integral to the consultation and offered more functionality. Although there are now only three major suppliers of general practice (GP) computer systems, there were originally multiple small vendors. The first systems had their functionality developed to meet the needs of the GP customer.<sup>1</sup> Subsequently the health service has started to impose standards on and required specific functionality of GP computer suppliers.<sup>2,3</sup> EMIS,<sup>4</sup> InPractice<sup>5</sup> and iSOFT<sup>6</sup> now dominate and share between them 90% of the market.<sup>7</sup>

Initially, computers made repeat prescribing easier and safer, with many practices keeping parallel paper records. More recently, practitioners have started to keep comprehensive records on computer.<sup>8</sup> Additionally, in the consultation they also have access to: pathology results provided electronically direct from the laboratory; scanned-in clinical correspondence received into the practice on paper; computer-generated prompts to improve the quality of chronic disease management; a wide range of knowledge support; and on-line booking of specialist appointments.<sup>9–12</sup> Although they perform similar tasks, the interfaces of the different brands of computer system are quite dissimilar; this is even true for different versions of the same brand. For example, EMIS LV, the EMIS traditional version, is quite different from the more modern PCS version.

Unified modelling language (UML) is an industry-standard notation for modelling software artefacts.<sup>13</sup> Although commonly used in software engineering to describe system processes and to obtain analysable frameworks,<sup>14–16</sup> UML is a general-purpose modelling language. It can also be used for non-software systems. There is no published literature on the use of UML to appraise the impact of the clinical computer system on the consultation.

We therefore carried out this study to explore the feasibility of using UML diagrams to compare the impact of different brands of computer systems on common elements of the general practice clinical consultation.

## Methods

We carried out a literature review of the common bibliographic databases and found no record of the use of UML to observe the clinical consultation.

We used three data collection techniques to construct the UML model: (1) multi-channel video; (2) user action recorder (UAR); and (3) pattern recognition software

(PRS). Multi-channel video provides more information about the consultation and use of the clinical computer system than single-channel video, commonly used for assessment of consultation quality.<sup>17–19</sup> UAR stores the details of keyboard and mouse use. PRS can be used to capture precise detail about the timing of the doctor's and patient's movement and body language.<sup>20</sup>

We recorded a series of simulated clinical consultations using four GP clinical system types: EMIS LV, EMIS PCS, iSOFT Synergy and IPS Vision. Four general practitioners and three actors played the roles of doctors and patients respectively. The systems were pre-loaded with simulated medical histories. Actors followed a detailed script to ensure consistency. The GPs consulted in a familiar environment. The consultations ran as 'real' consultations, other than that no physical examinations took place beyond measurement of pulse or blood pressure. Each clinician undertook the same three consultations. One of these, a hypertension monitoring review, was used for this study.

Our multi-channel video system had four channels (see Figure 1). One video camera captured a wide-angle view of the doctor and patient interaction; this is the conventional single camera setting. The second camera was positioned behind the patient just over his shoulder height. This captured the doctor's interactions, facial expressions and direction of gaze during the sessions. The third camera, positioned behind the doctor, captured the similar interactions of the patient. Special software installed in the GP computer system (Camtasia studio V3.0) recorded the screen sequences. Microphones attached to the video cameras recorded the conversations. We composed the final multi-channel footage by combining and synchronising the recordings of the three cameras and the output of the screen capture software.

User action recording measured the doctor's use of the computer keyboard and mouse, and created event and timing logs (see Figure 2). We developed this software in-house. For the keyboard, it recorded the values of the keyboard's character key presses or navigation keys. It also recorded the co-ordinates of the mouse pointer and the left or right clicks. The log file recorded each of the input event occurrences against a timestamp set at intervals of 10 milliseconds.

The PRS utilised a standard web camera attached to a dedicated computer to analyse the video recording for movement patterns. We could instruct the software to detect movements within predefined virtual areas called 'frame rectangles' in the video stream (see Figure 3). This software identifies the movements within these areas by analysing the changes in image pixels. We placed frame rectangles over the patient's and doctor's upper bodies and over the computer keyboard; our experiential learning is that this records most non-verbal communications.<sup>21</sup> We derived four

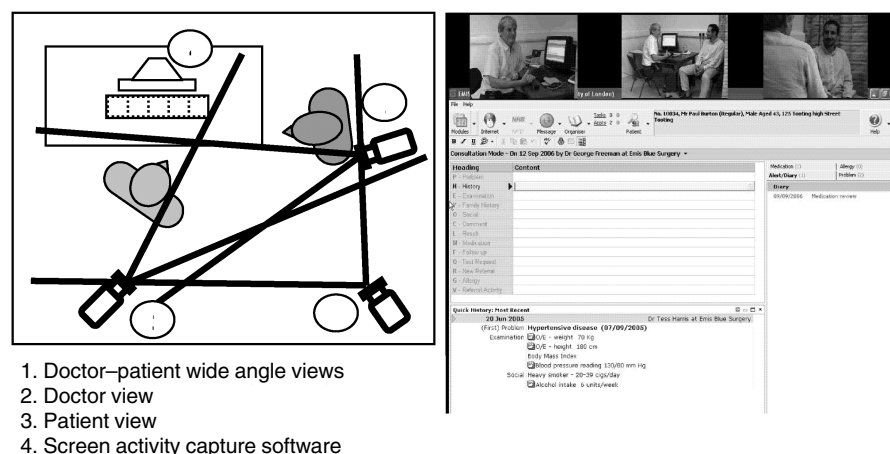


Figure 1 Multi-channel video setup and final output

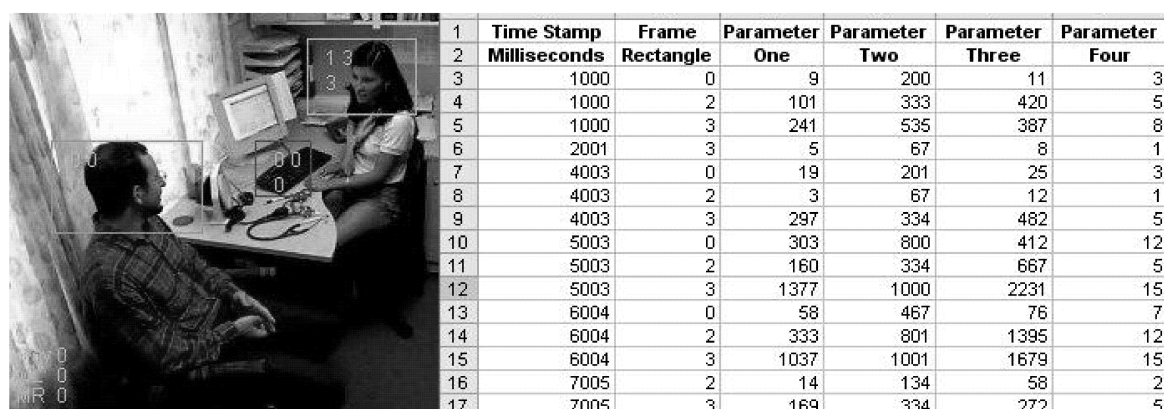


Figure 2 Pattern recognition application and log file

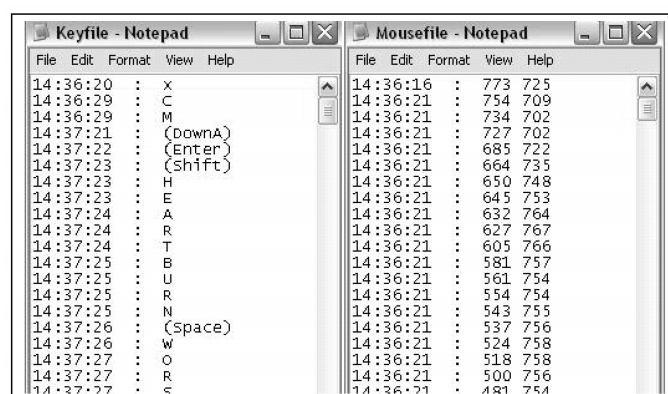


Figure 3 User Action Recorder log files

quantitative scores based on the changes within frame rectangles. PRS records these measurements in a log file against timestamps.

We used two of the 15 different diagram types available in UML (version 2.0)<sup>22</sup> to model the consultation.

The models were initially created using StarUML software,<sup>23</sup> an open source UML platform. The two main types of diagrams we used were 'class diagrams' to define structure and 'sequence diagrams' to model the behaviour. The 'class diagram' represents the main

entities within a system. We defined the doctor, patient and the computerised medical record system as the main classes. We then went on to use 'sequence diagrams' to define the principal activities within the consultation (such as prescribing), looking to identify those which might be common to as well as not represented in each of the consultations reviewed (for example, referral). We used an established list of consultation components, adding to this where needed.<sup>24</sup> Next we studied these sequence diagrams in detail, comparing two common activities identified in all the consultations, as we felt this would provide the most valid comparison – problem definition (that is, developing a shared understanding of why the patient has come to see their GP) and prescribing. On the sequence diagram, vertical 'lifelines' run downwards with time from the three entities. Vertical oblong boxes indicate the focus of control. Arrows represent interactions between these entities (see Figure 4).

The sequence diagrams were created as a three-stage process. First we created them based on the UAR log files. We reviewed them to identify the blocks of computer use with their start and end times. We plotted these findings to the doctor and computer lifelines; this should define their focus of control boxes and the message passing arrows between them. We then reviewed the PRS output log files to distinguish the non-verbal interactions of doctor and patient. We identified the timestamps for their movement changes. These time series were marked in the sequence diagram together with the focus of control box outlines.

The final step was to enhance the sequence diagram skeleton using the multi-channel video outputs to inform the purpose and results of each interaction. We viewed the computer interface activities to detail the doctor and computer interactions. Finally we annotated the sequence diagram to explain the data flows associated with each interaction.

## Results

We selected similar consultations for our analysis. All of them involved a GP, a single patient and the use of

the computer. The common consultation elements present were: review of medical records; greeting; problem definition; clinical measurement (BP measure); agreed action plan; prescribing; summary; and closure. Data entry using templates, drug reaction warning or alternate drug suggestion appeared in two consultations. The median number of items coded in each consultation was 5 (range 3–7) and the proportion of time spent coding was 11%. For technical reasons the recording of the simulated hypertension recording using IPS Vision failed; we had to substitute this using a similar consultation filmed as part of another study. This substitution also contained problem definition and prescribing stages related to a hypertension monitoring; the doctor role was played by a GP familiar with Vision, and there was a similar simulated medical history but with different patient demographics and a different actor playing the patient role. The consultation length and time taken to complete each consultation element, data recording and interactions are presented in Table 1.

The multi-channel video and UAR provided a highly usable overview of the consultation. UAR recorded all keyboard strokes, spelling out the words written and the mouse clicks. We directly mapped the timestamps of these events to the doctor–computer interaction sequences. There were fundamental differences in UAR outputs between the predominantly keyboard-driven GP systems (EMIS LV) and the graphical user interface style systems (EMIS PCS, IPS Vision and iSOFT Synergy).

We were unable to utilise the output of the PRS as we had intended. We did not manage to capture non-verbal communication consistently, though keyboard activity correlated better with UAR activity. Only short segments of the log file output clearly correlated with non-verbal communication. Changes in direction of gaze could not be measured. PRS log files were best at identifying the duration the doctor had his hands moved over or away from the keyboard and when key presses were performed.

The final sequence diagram modelled the consultation session as a two-dimensional process. It consists of sequence of activities, also indicating involvement of each element (see Figure 5).

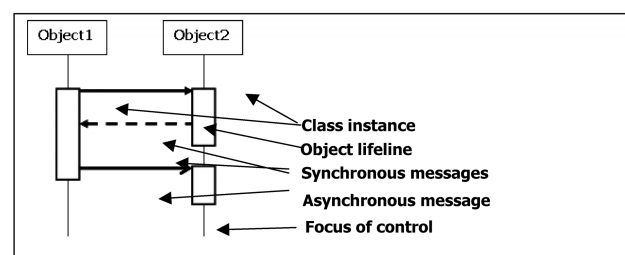


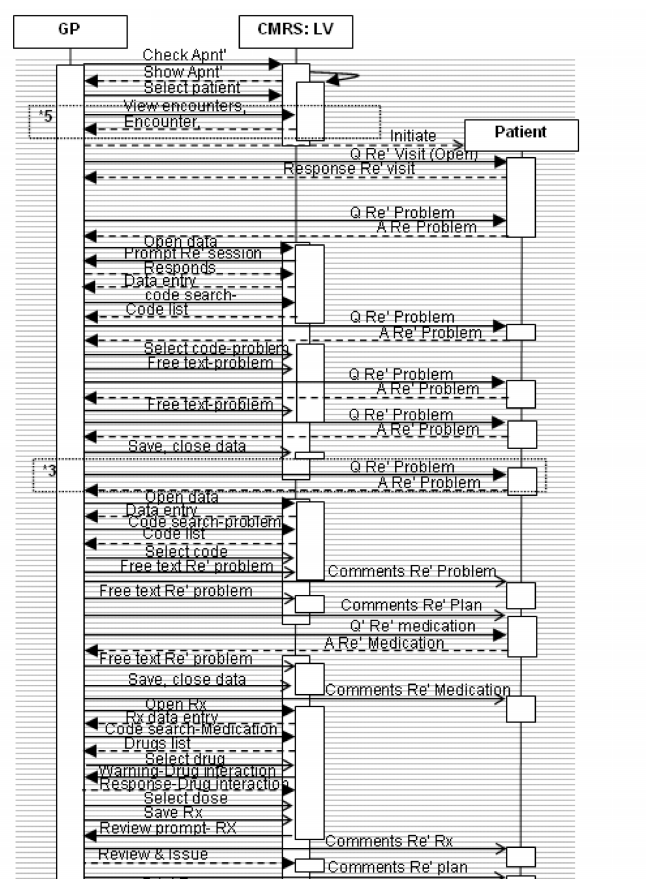
Figure 4 Sequence diagram introduction



**Table 1** Elements of the consultation defined from the sequence diagrams of four different clinical systems

Sequence diagram element (item definition for each element is specified within the brackets)	EMIS LV				EMIS PCS				iSOFT Synergy				IPS Vision			
	Time(s)	Items	% time	Mean time(s)	Time(s)	Items	% time	Mean time(s)	Time(s)	Items	% time	Mean time(s)	Time(s)	Items	% time	Mean time(s)
Reviewing past items (encounter/Rx summary)	26	5	3.27	5.20	15	4	1.94	3.75	11	7	1.02	1.57	16	3	3.05	5.33
Keyboard interaction (key stroke)	208	156	26.16	1.33	123	241	15.93	0.51	**	**			162	195	30.86	0.83
Mouse interaction (mouse click)	57	19	7.17	3.00	62	31	8.03	2.00	71	21	6.57	3.38	83	23	15.81	3.61
Alerts (message or prompt)	6	1	0.76	6.00	21	6	2.72	3.50	14	3	1.30	4.67	8	4	1.52	2.00
Coded data entry (Read code/drug)	76	4	9.56	19.00	15	3	1.94	5.00	118	7	10.92	16.86	104	6	19.81	7.26
Freetext data entry (word)	151	39	18.99	3.87	183	46	23.07	3.98	153	27	14.17	5.67	127	31	24.19	4.10
Doctor–patient synchronous (question and answer pair)	413	7	51.94	59.00	471	6	61.01	78.50	508	14	47.04	36.29	200	11	38.09	18.18
Doctor–patient asynchronous (comment/ explanation)	206	12	25.92	17.17	154	5	19.95	30.80	368	12	34.07	30.67	215	12	40.95	17.92
Doctor–computer synchronous (action and response)	223	16	28.05	13.94	247	11	32.00	22.45	389	19	36.02	20.47	94	10	17.90	9.40
Doctor–computer asynchronous (action/ event)	64	14	8.05	4.57	46	32	5.96	1.44	140	11	12.96	12.73	121	14	23.05	8.64
Total consultation time(s)	<b>795</b>				<b>772</b>				<b>1080</b>				<b>525</b>			

\*\* Could not obtain data due to technical fault



**Figure 5** UML process model of a full consultation

UML models of the problem definition stage reflect a wide variation of computer use, and in some situations the activity structure or length is related to the GP system brand (see Figure 6). The problem definition process was initiated by either viewing previous records of problems held in the computer or asking open questions from the patient; this is represented by synchronous messages passed between doctor-computer and doctor-patient respectively. In the first approach, one system presented the medications and problems together. Therefore in this system we could frequently observe situations where discussion of medication was included in the conversation. We did not see this pattern in the systems that had separate windows to display these two areas. The sequence diagrams also showed the doctor making use of available opportunities while interacting with the patient to capture data into the patient record, for example, the patient mentioning something about a family history while explaining the symptoms could prompt the doctor to record the relevant family history code. This type of unplanned data entry often occurred in the systems that demanded no or fewer navigation steps to get into an appropriate data entry stage. When the doctor searches for a code to record a

problem, first its title (or a few letters) is entered and then the system provides the appropriate list of codes. Screen capture showed variations of the number and order of items presented. Heights of the 'focus of control' rectangles indicated the relative duration taken to review this list of items; there were occasions of straight selection as well as reiterating the entire process to obtain more specific codes. When a long list of items is presented, the doctor has opted to reword or expand the problem title rather than scrolling down the list. They are represented by additional synchronous arrows from the doctor to the computer. One system brand which had a sophisticated feature of automatically displaying the appropriate structured code by analysing the freetext as it is typed in (this technique is known as semantic-auto completion), actually lengthened the coding process in our pilot. The GP had to do extra work to ignore the suggested code or to do corrections or to overwrite them. For the systems that have separate windows for coded data entry, more events were recorded, but this did not seem to cause any lengthening of the computer interaction. Freetext data entry led to a longer computer focus and keyboard use; however, parallel running doctor-patient interactions were still frequently visible.

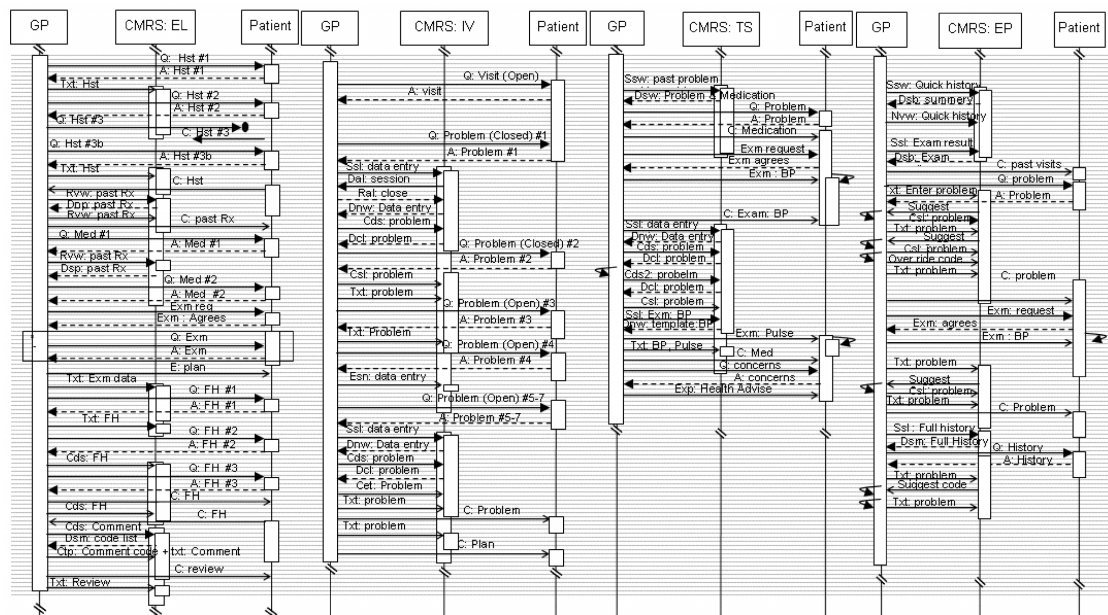


Figure 6 UML model extractions of the problem definition stage of four different clinical systems

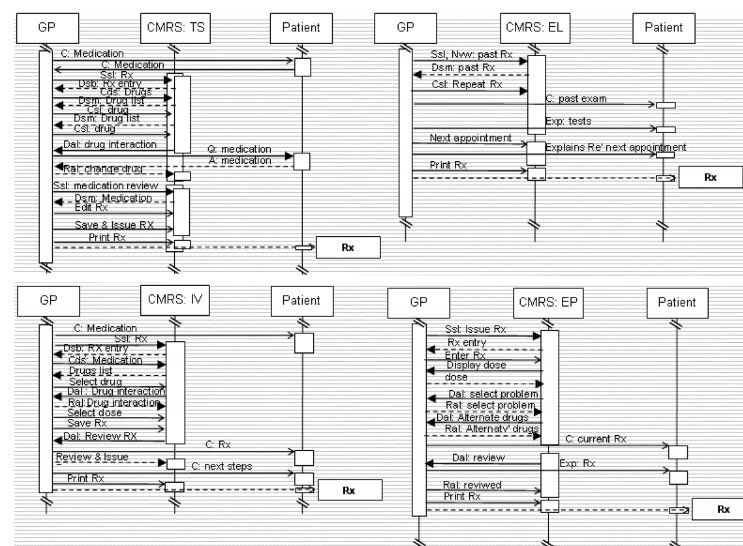


Figure 7 UML model extractions of the prescription stage of four different clinical system brands

For one session, data entry was disturbed by a prompt regarding the consultation schedule. This demanded a response from the doctor and halted the patient–doctor communication. Systems that have combined several consultation topic areas into a single interface had less-structured sequence flow, compared to those with a separate data entry window for each. Data entry templates took less computer focus time, computer interactions and recorded more structured data. On one occasion a template even reminded the GP to complete an examination step he had overlooked.

The prescription stage showed predominant doctor–computer interaction in all system brands (see Figure 7). Systems that have ‘new prescription’ shortcuts,

rather than having it as an option within a separate prescription window, required less time. However, the UML model of the second type showed the occurrence of doctor–patient asynchronous messages, for example, the GP commenting about the previous medication. Systems that have drug reaction warning or alternative drug indication systems lengthened the computer focus. Drug reaction warnings demanded a GP response and in some situations this was preceded by synchronous interaction with the patient to verify current prescriptions. Repeat prescriptions showed fewer interactions. Another system brand prompts the doctor to review the medication before it is issued. On one occasion this resulted in a computer–patient

parallel interaction, where the doctor read the prescriptions aloud while referring to the data entry window. The prescribing interactions were usually followed by discussions regarding the next steps and handing over the prescription to the patient.

## Discussion

### Principal findings

UML models provide a mechanism for comparing the impact of different brands of computer systems on a standardised clinical consultation.

The combination of multi-channel video and the user activity recording software allows the creation of detailed UML models of the clinical consultation. All four channels of the multi-channel video usefully capture the processes within a computer-mediated consultation. The user action recording produces an accurate time-sequence of computer use. It is useful in generating the initial draft of the UML diagram. Although the PRS holds the allure of more objectively capturing details of body language, its lack of consistency made it hard to use.

### Implications

This method, using UML, potentially provides a mechanism for comparing how different brands of computer systems impact on the consultation. A larger study might enable identification of more suitable design features for clinical systems; for example, one prescribing approach could be more efficient compared with another. There is the potential to develop this method for testing and comparing clinical software using standard reference consultations preloaded onto the computer system and using actors as patients.

The UML model could be more readily interpretable by software engineers, and might lead to the development of systems which blend smoothly into the consultation.

### Limitations of the study

The principal limitation of this pilot was its size. It is impossible to know whether the difference between the consultations was due to variations between the four GPs rather than between the software they were using. Although we attempted to simulate a typical consultation, pressure to achieve quality targets, interruptions and other factors may have been different from real-life situations.

### Comparison with literature

This study pilots a more objective approach to consultation modelling. Existing doctor–computer–patient interaction evaluation methods are time-consuming and more subjective.<sup>24</sup> Although UML has been used to assess clinical processes<sup>25</sup> and the consequences of alternative informatics solutions in health care,<sup>26</sup> it has not previously been used to model the clinical consultation. The approach adopted fits with current guidance on evaluation.<sup>27</sup>

### Call for further research

Repeating this study with a larger sample of GPs and range of cases would provide some indications as to the extent to which different clinical system design features perform within consultations.

## Conclusion

The UML model can be used to analyse the clinical consultation. It can be used by both clinicians and informaticians to review, analyse and communicate improvements to the computer-mediated consultation. Computer systems capable of managing the information collaboratively with the clinician and blending into the social dimension of the consultation process could result in the consultation being more likely to meet the patient's expectations.

### ACKNOWLEDGEMENTS

We thank Eben Willson and Toby Fallon of Main Communications, who allowed us to use their Algol PRS software, Vickie Wood for a review of the manuscript, and Ian Herbert for helpful comments on the initial version of this paper.

### REFERENCES

- 1 Pemberton J, Buehring A, Stonehouse G, Simpson L and Purves I. Issues and trends in computerisation within UK primary health care. *Logistics Information Management* 2003;16:181–90.
- 2 NHS Connecting for Health. *General Practice Infrastructure Specification*. 2007. [www.connectingforhealth.nhs.uk/systemsandservices/gpsupport/gpsoc/gpspec.pdf](http://www.connectingforhealth.nhs.uk/systemsandservices/gpsupport/gpsoc/gpspec.pdf)
- 3 Department of Health. *Building the Information Core: implementing the NHS Plan*. Leeds: Department of Health, 2001.
- 4 EMIS (Egton Medical Information Systems). [www.emis-online.com/primary-care-systems](http://www.emis-online.com/primary-care-systems)
- 5 IPS (In Practice) Vision. [www.inps3.co.uk](http://www.inps3.co.uk)

- 6 iSOFT Synergy. [www.isoftware.com/corporate/products/2590.asp](http://www.isoftware.com/corporate/products/2590.asp)
- 7 Royal College of General Practitioners. *Information Management and Technology in General Practice*. 2005. [www.rcgp.org.uk/pdf/ISS\\_INFO\\_07\\_Feb05.pdf](http://www.rcgp.org.uk/pdf/ISS_INFO_07_Feb05.pdf)
- 8 Ash JS and Bates DW. Factors and forces affecting EHR system adoption: report of a 2004 ACMI discussion. *Journal of the American Medical Informatics Association* 2005;12:8–12.
- 9 Preece J. *The Use of Computers in General Practice* (4e). London: Churchill Livingstone, 2000.
- 10 Schade CP, Sullivan FM, de Lusignan S and Madeley J. e-Prescribing, efficiency, quality: lessons from the computerization of UK family practice. *Journal of the American Medical Informatics Association* 2006;13:470–5.
- 11 Tai SS, Donegan C and Nazareth I. Computers in general practice and the consultation: the health professionals' view. *Health Informatics Journal* 2000;6:27.
- 12 Morris CJ, Savelyich BSP, Avery AJ, Cantrill JA and Sheikh A. Patient safety features of clinical computer systems: questionnaire survey of GP views. *Quality and Safety in Health Care* 2005;14:164–8.
- 13 Douglass BP. *Real Time UML: advances in UML for real-time systems*. Reading, MA: Addison-Wesley, 2004.
- 14 Sommerville I. *Software Engineering* (4e). Reading, MA: Addison-Wesley, 1992.
- 15 Blanchard BS and Fabrycky WJ. *Systems Engineering and Analysis* (3e). Englewood Cliffs, NJ: Prentice-Hall, 1998.
- 16 Haug M, Olsen EW and Bergman L. *Software Process Improvement: metrics, measurement and process modeling*. Berlin: Springer, 2001.
- 17 Theadom A, de Lusignan S, Wilson E and Chan T. Using three-channel video to evaluate the impact of the use of the computer on the patient-centredness of the general practice consultation. *Informatics in Primary Care* 2003; 11:149–56.
- 18 Pendleton D, Schofield T, Tate P and Havelock P. *The Consultation: an approach to learning and teaching*. Oxford: Oxford University Press, 1984.
- 19 Coleman T. Using video-recorded consultations for research in primary care: advantages and limitations. *Family Practice* 2000;17:422–7.
- 20 Mouline M, de Lusignan S, Freeman G *et al*. Assessing the impact of recording quality target information on the GP consultation using multi-channel video. Medinfo 2007, Brisbane.
- 21 de Lusignan S, Wilson E, Dyble A, Grant T, Theadom A and Chan T. The feasibility of using pattern recognition software to measure the influence of computer use on the consultation. *BMC Medical Informatics and Decision Making* 2003;3:12.
- 22 Rosenberg D and Scott K. *The Object Primer: agile model driven development with UML 2* (3e). Reading, MA: Addison-Wesley, 2001.
- 23 Star UML: the Open Source UML/MDA Platform. [www.staruml.com](http://www.staruml.com)
- 24 de Lusignan S, Wells SE, Russell C, Bevington WP and Arrowsmith P. Development of an assessment tool to measure the influence of clinical software on the delivery of high quality consultations. *Medical Informatics and the Internet in Medicine* 2002;27:267–80.
- 25 Boye N and Veirum NE. Ontology-based, medical domain-specific, use-case driven EMRs for use in clinical quality assurance and passive decision support. *Studies in Health Technology and Informatics* 2000;70: 36–8.
- 26 Saboor S, Ammenswerth E, Wurz M and Chimiak-Opoka J. *MedFlow: improving modelling and assessment of clinical processes, connecting medical informatics and bioinformatics*. MIE2005. Amsterdam: IOS Press, 2005.
- 27 Ammenwerth E, Graber S, Herrmann G, Burkle T and Konig J. Evaluation of health information systems: problems and challenges. *International Journal of Medical Informatics* 2003;71:125–35.

#### CONFLICTS OF INTEREST

None.

#### ADDRESS FOR CORRESPONDENCE

Simon de Lusignan  
Primary Care Informatics  
Division of Community Health Sciences  
St George's University of London  
SW17 0RE  
UK  
Tel: +44 (0) 208 725 5661  
Fax: +44 (0) 208 725 3584  
Email: [slusigna@sgul.ac.uk](mailto:slusigna@sgul.ac.uk)

*Accepted October 2007*

